Land Surface Modeling and Data Assimilation

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Major R2O Achievements

3-yr project (6/2010 – 5/2013); budget: $340K

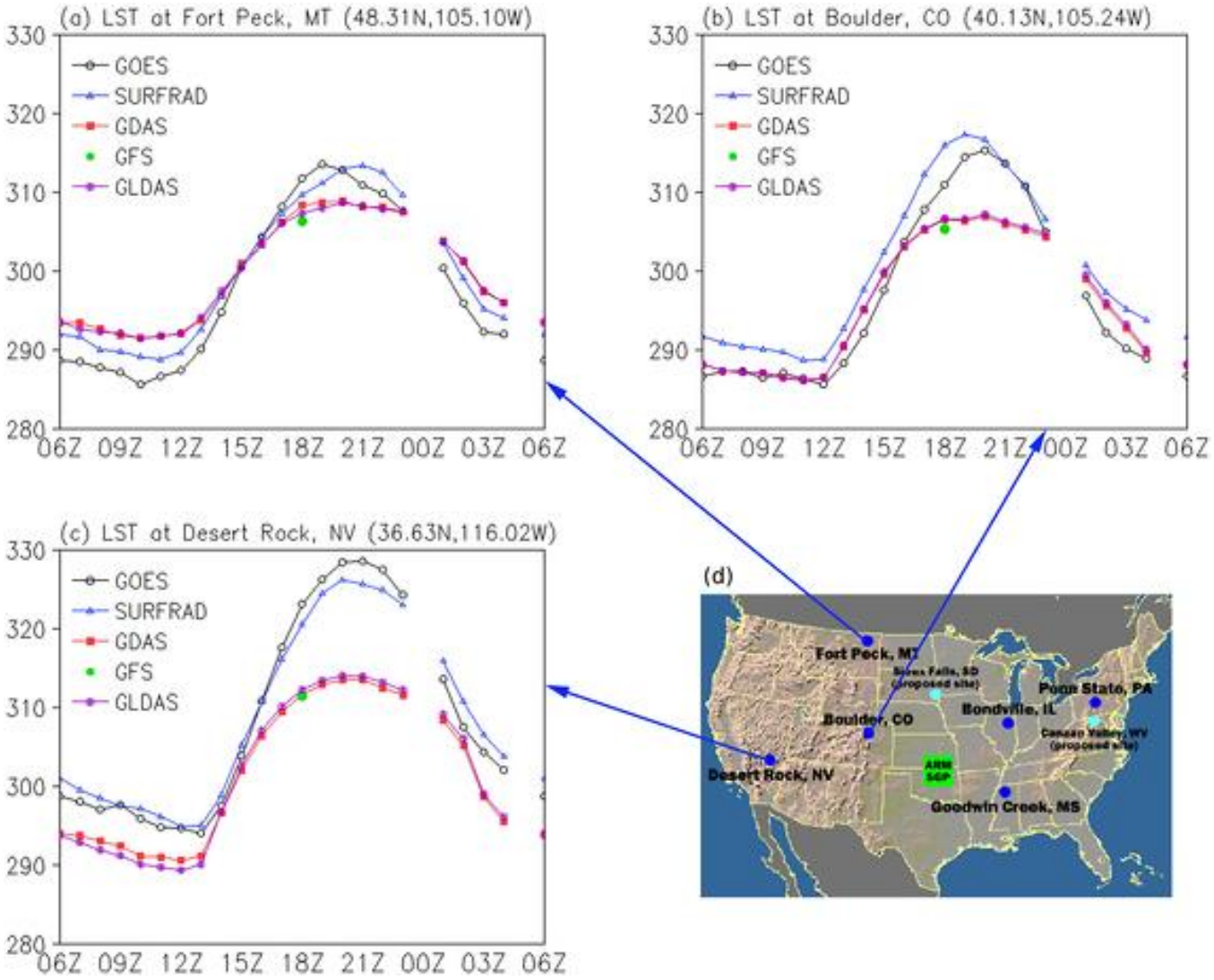
Improvements in Noah daytime Ts were implemented in GFS in May 2011

Noah snow improvements have been tested in GFS and are ready for implementation;

Noah snow improvements were released in WRF version 3.5 in April 2013

Noah-MP has become a land model option in WRF

1. Skin temperature over semi-arid regions

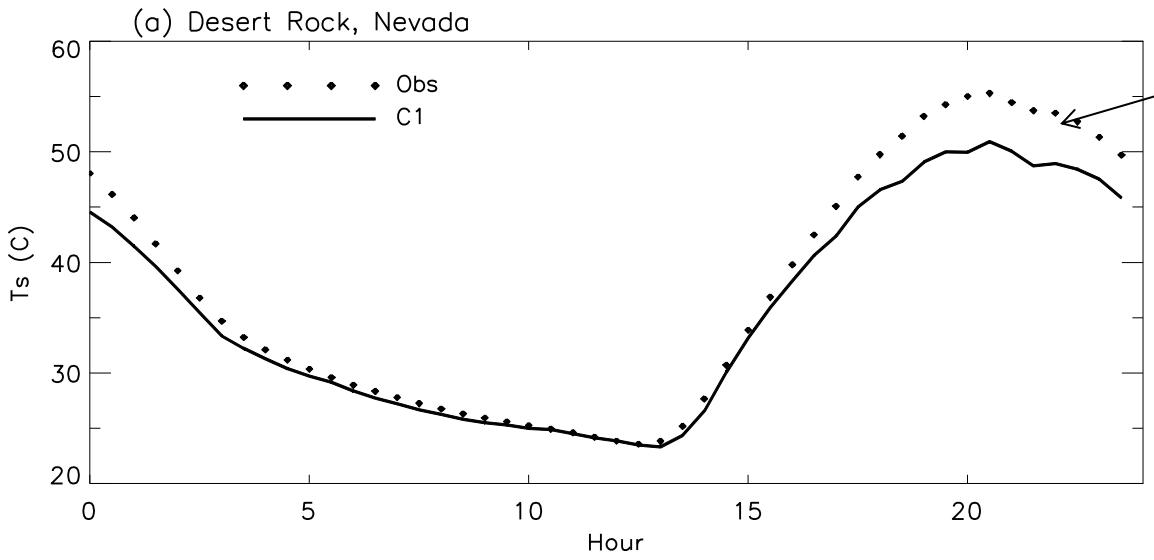


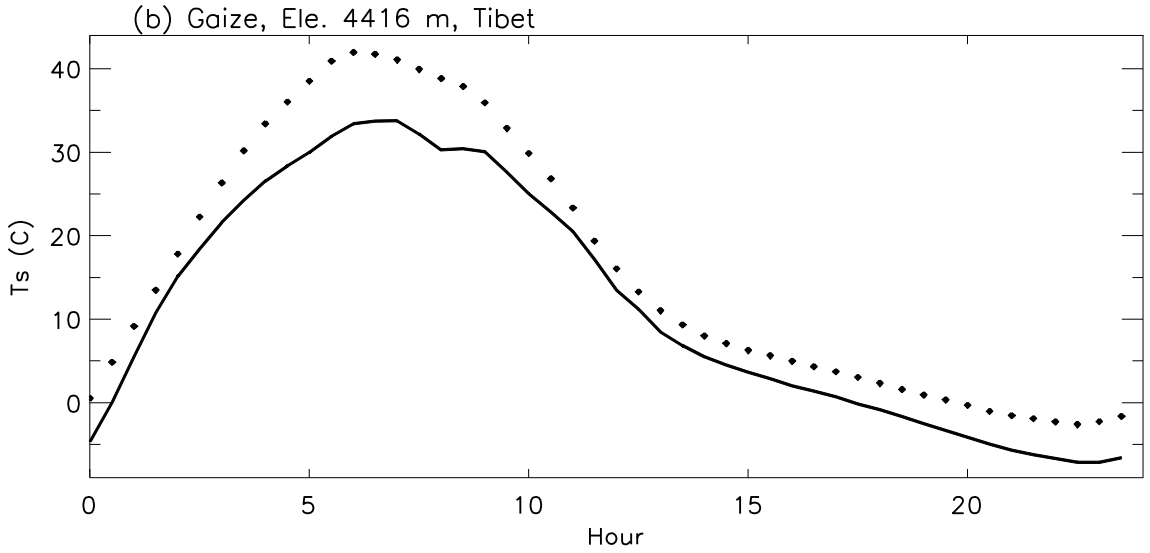
Zheng et al. (2012)

July 2007

CLM has a similar problem

Obs





Zeng et al. (2012)

Question

Can we develop unified formulations to improve both Noah and CLM in the simulation of the Ts diurnal cycle over arid regions?

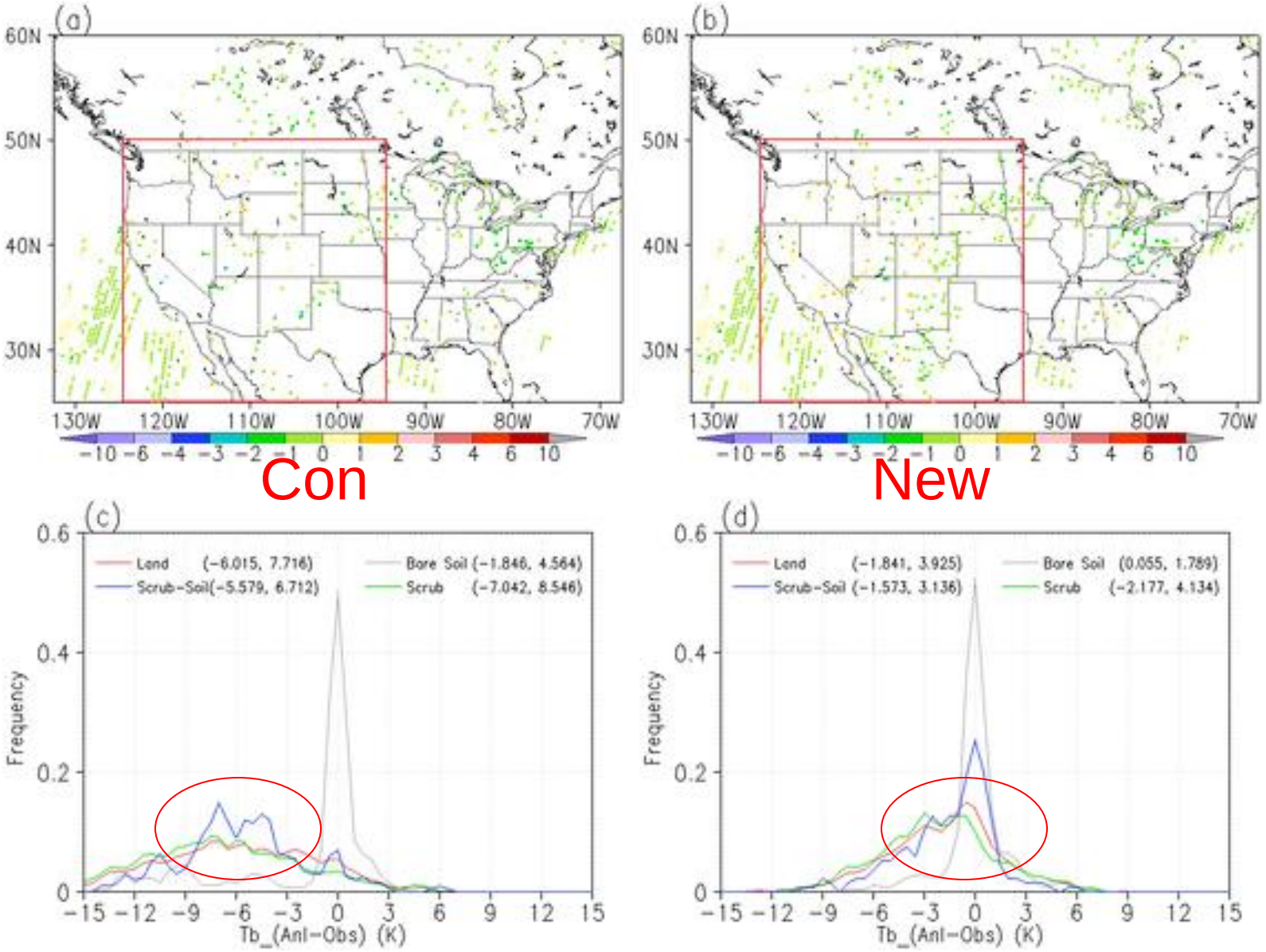
Yes (Zeng et al. 2012; Zheng et al. 2012). Main ideas:

To improve the formulations of roughness lengths for momentum and heat;

To improve the treatment of stable turbulence in the atmospheric boundary layer through the interplay between sensible and ground heat fluxes

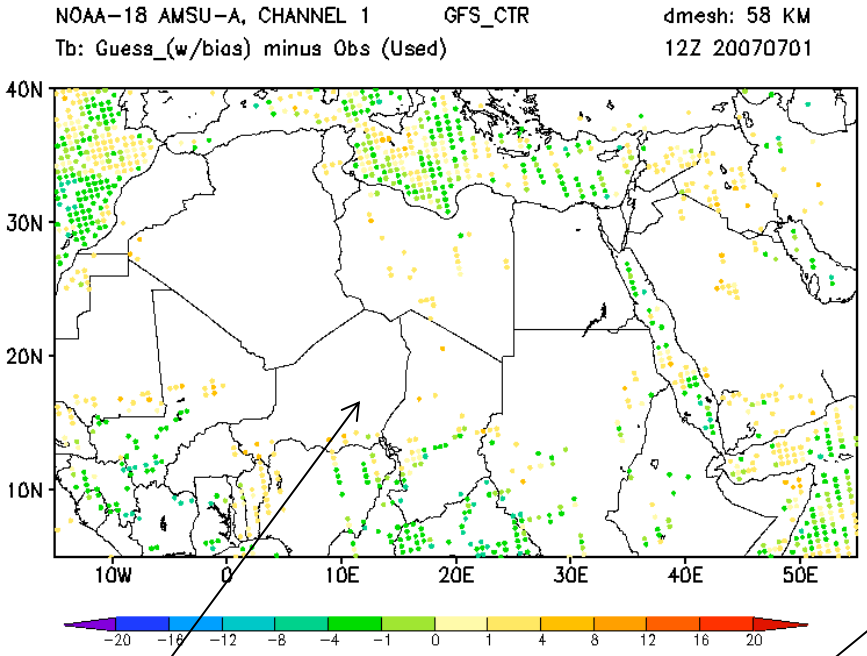
Mean absolute deviation (K)

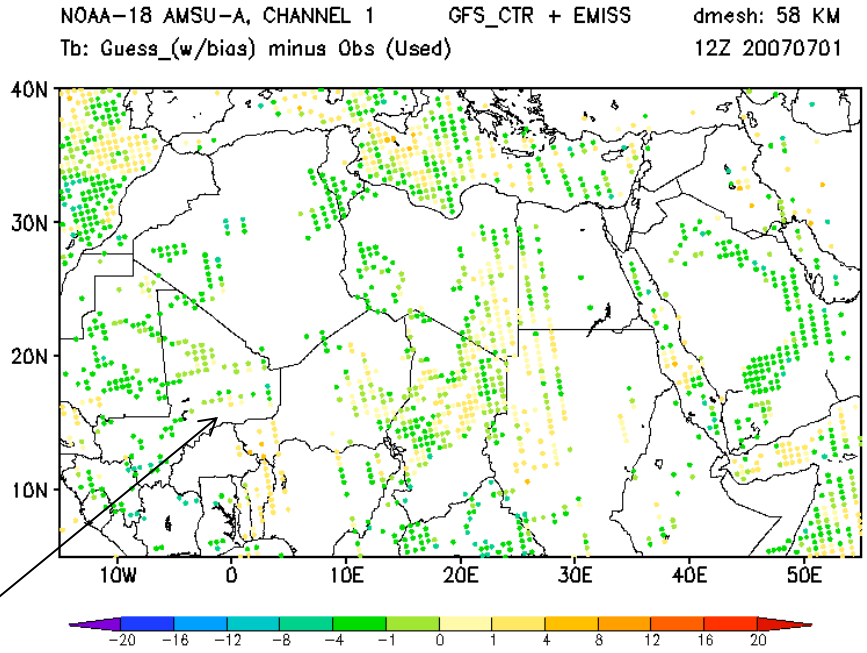
	Desert Rock	Gaize
Noah (Con)	2.8	5.8
Noah (New)	0.5	1.6
CLM (Con)	1.9	4.6
CLM (New)	0.7	1.8



T_b bias in satellite pixels used in GFS GSI (NOAA-17 HIRS-3 Ch. 8) (Zheng et al. 2012)

Tb simulation for NOAA-18 AMSU-A Ch. 1

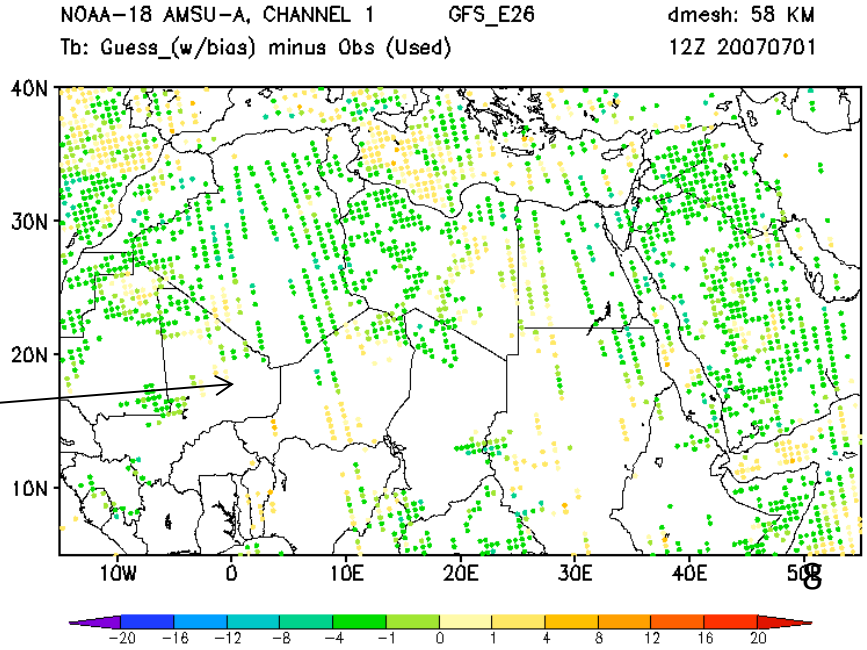




GFS CON

CON + improved surface emissivity

CON + improved surface emissivity
+improved Noah



Two ways for land data assimilation:

- Radiance assimilation (e.g., CRTM/GFS)

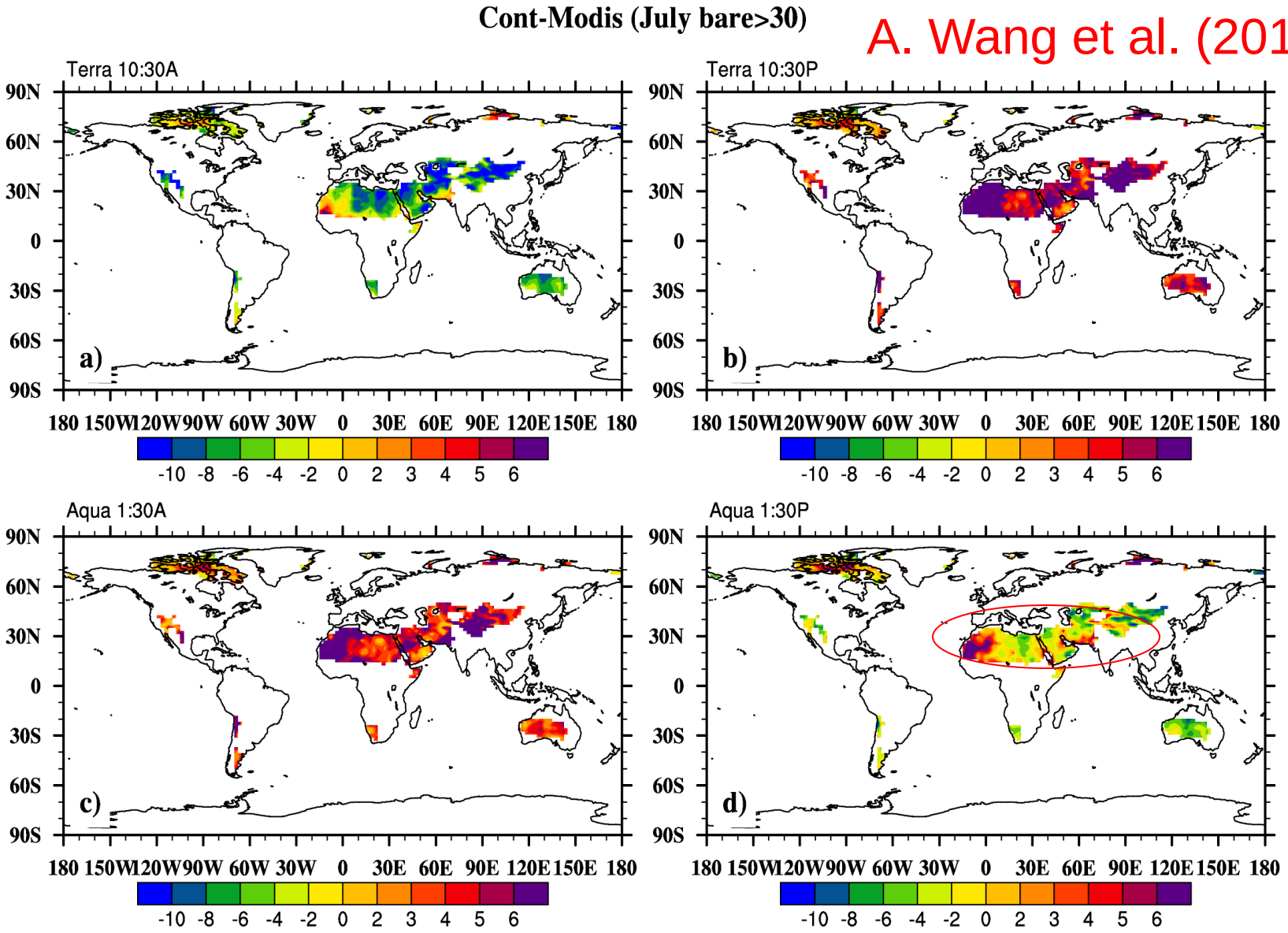
- Assimilation of satellite-retrieved quantities (e.g., GOES Ts, MODIS Ts)

NASA MODIS Terra (10:30am/pm) and Aqua (1:30am/pm) provide global clear-sky Ts data four times a day at high spatial resolution. The question is:

How can we use the 1-km MODIS clear-sky Ts data for model evaluation and assimilation?

CLM (31-day average) – MODIS (clear-sky) Ts
Jul 2003 (bare soil > 30% in CLM)

A. Wang et al. (2013)

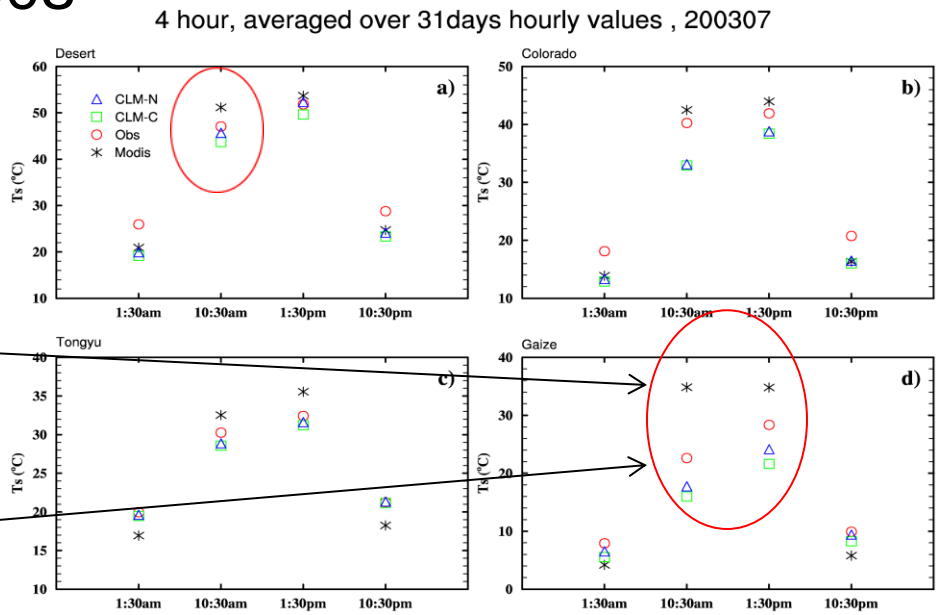


Jul 2003

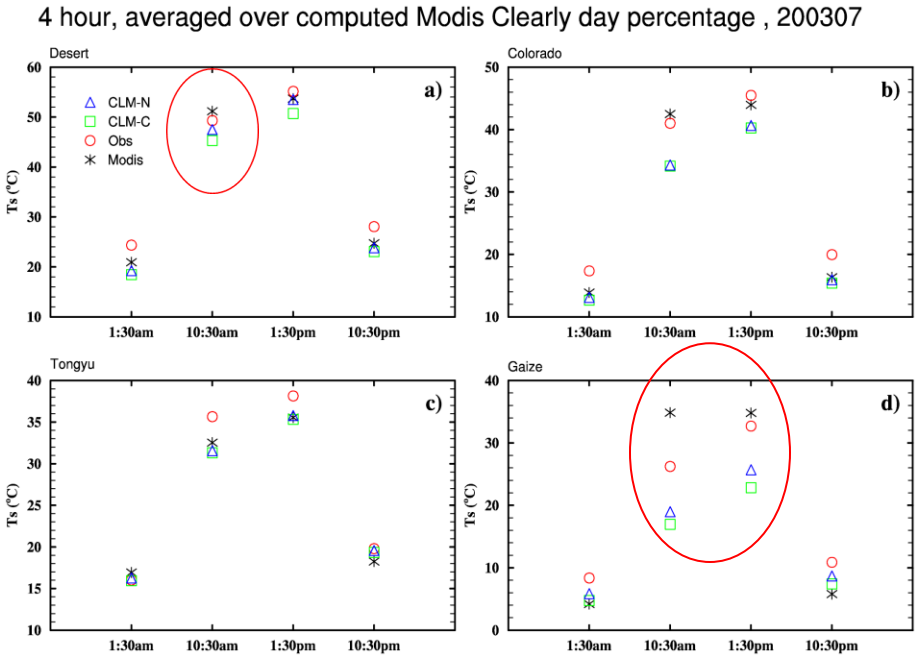
Clea-sky MODIS Ts vs 31 day-averaged obs and CLM Ts over four sites

MODIS

Obs



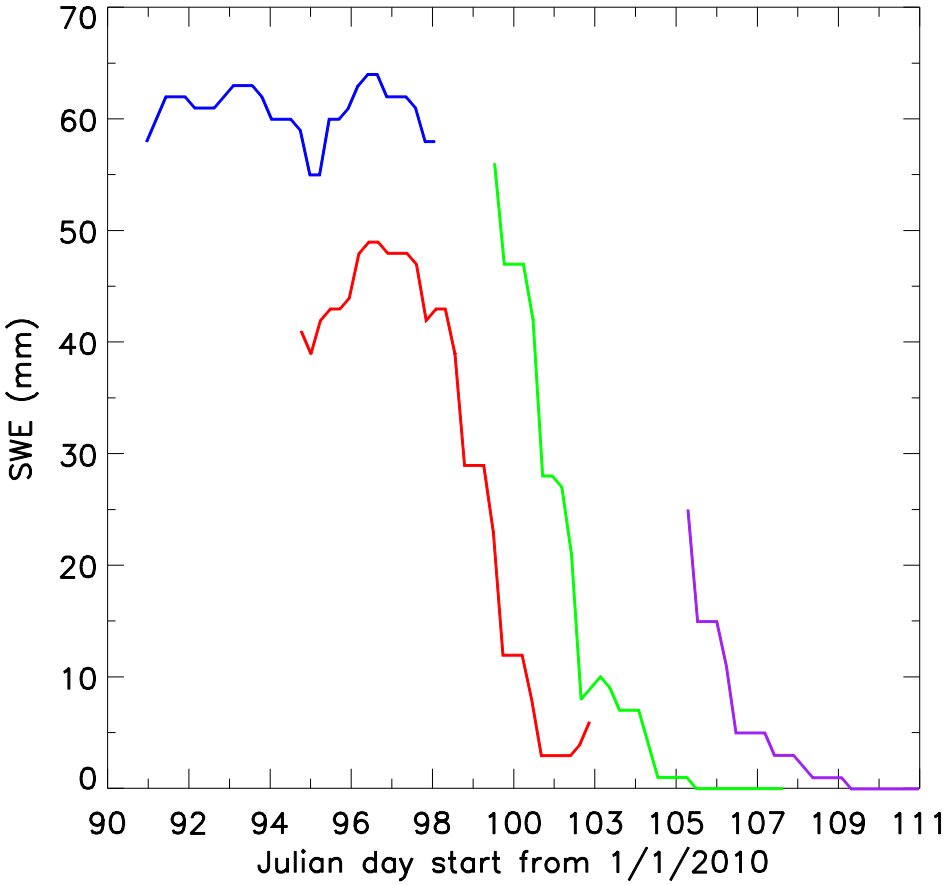
MODIS Ts vs. obs and CLM Ts with same clear-sky percentages based on SWd and LWd



2. Snow deficiency over forests

Snow data are assimilated, but the initial info is lost too fast.

Snow melts too fast.



GFS/Noah 7-day forecasting of snow over one forest grid in western U.S. in April 2010

Our solution (Wang et al. 2010):

Main ideas:

- Vegetation shading effect;
- Snow density adjustment;
- Under-canopy resistance;
- Revised Z0m under snow condition

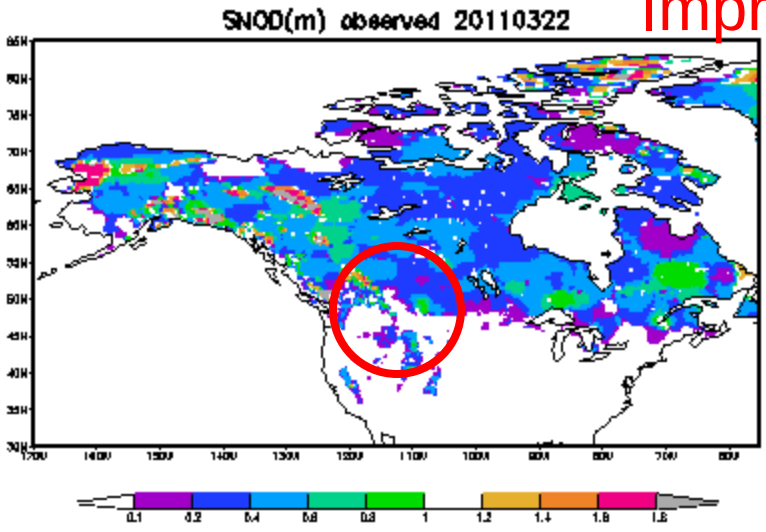
Using existing Noah model structure (for easy operational implementation)

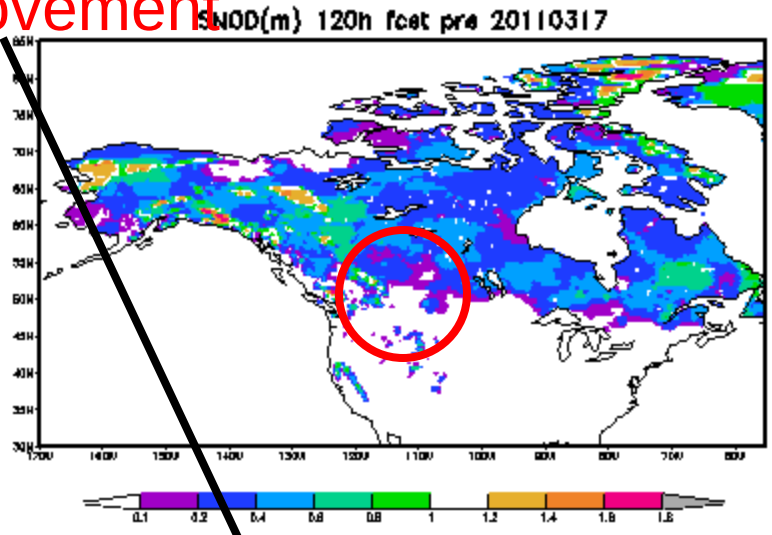
Alternative idea: Noah-MP

Snapshot 20110317 120h Forecast (Wei et al. 2012)

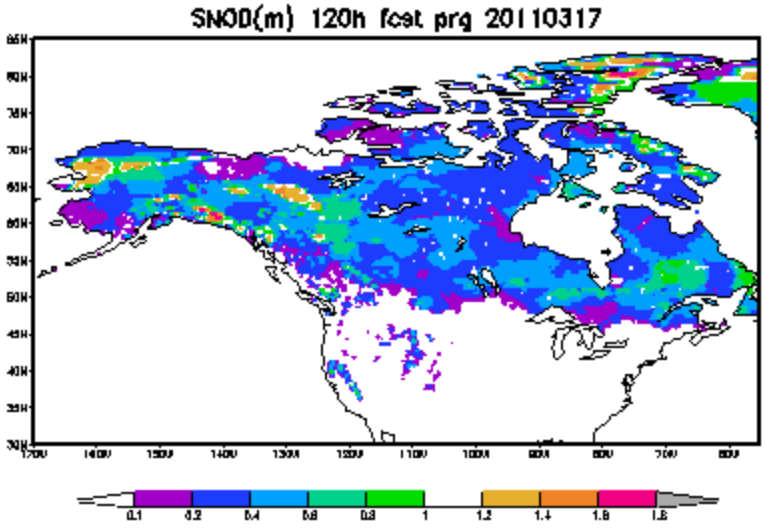
Improvement

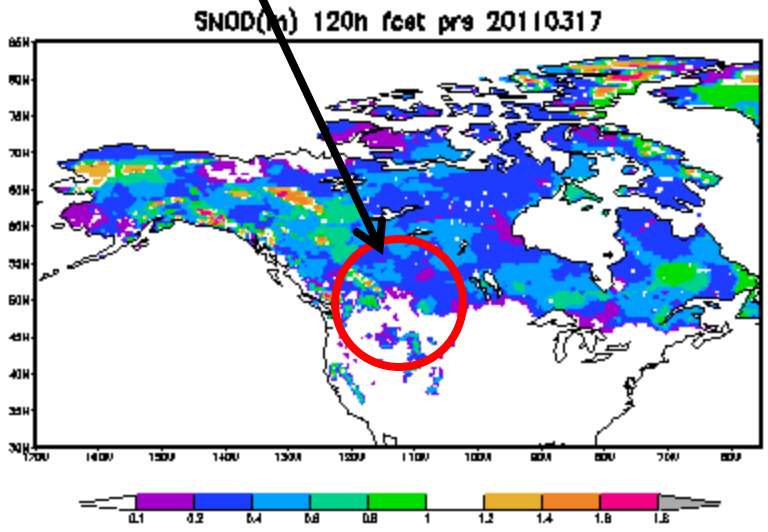
Obs





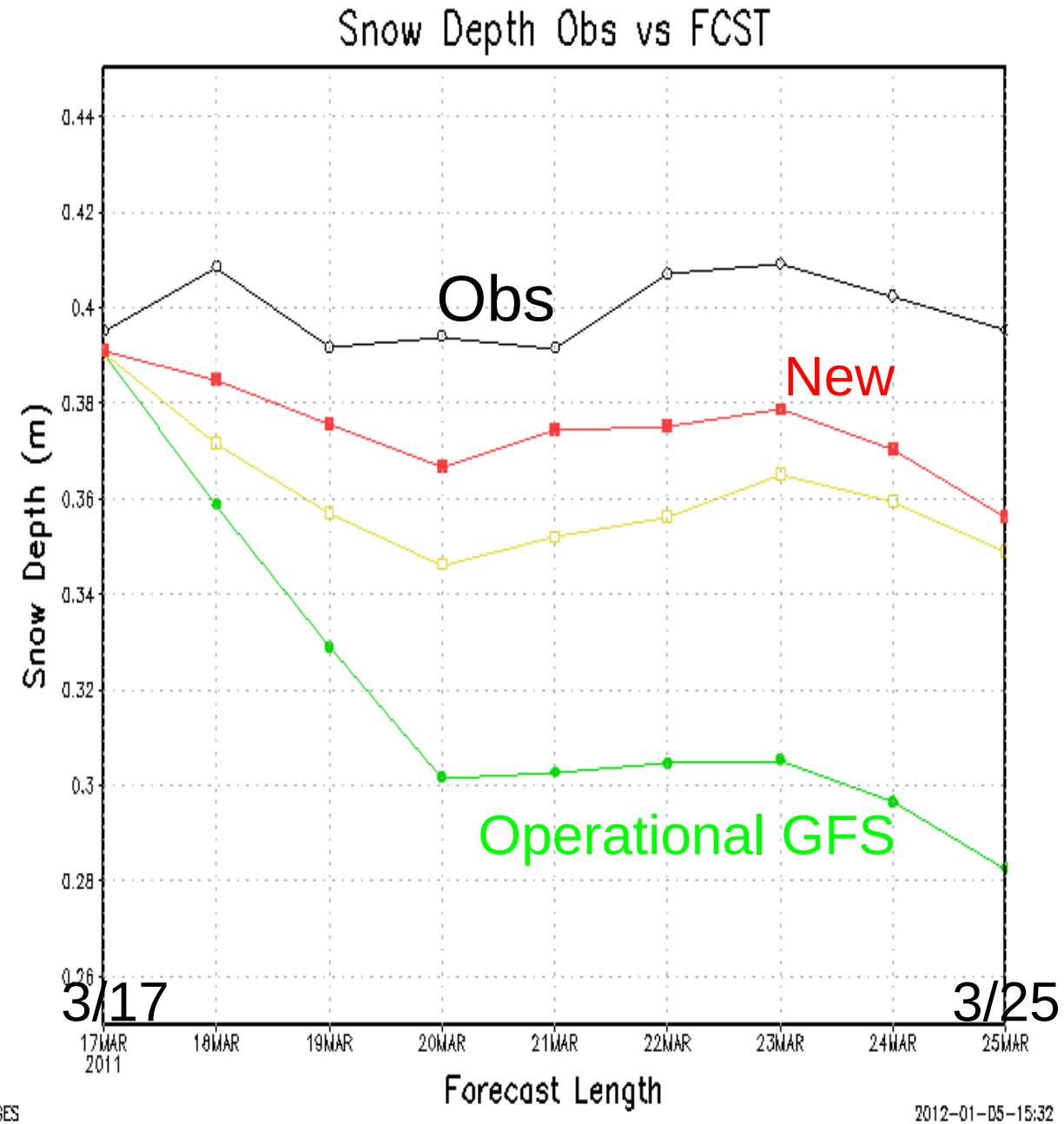
Con



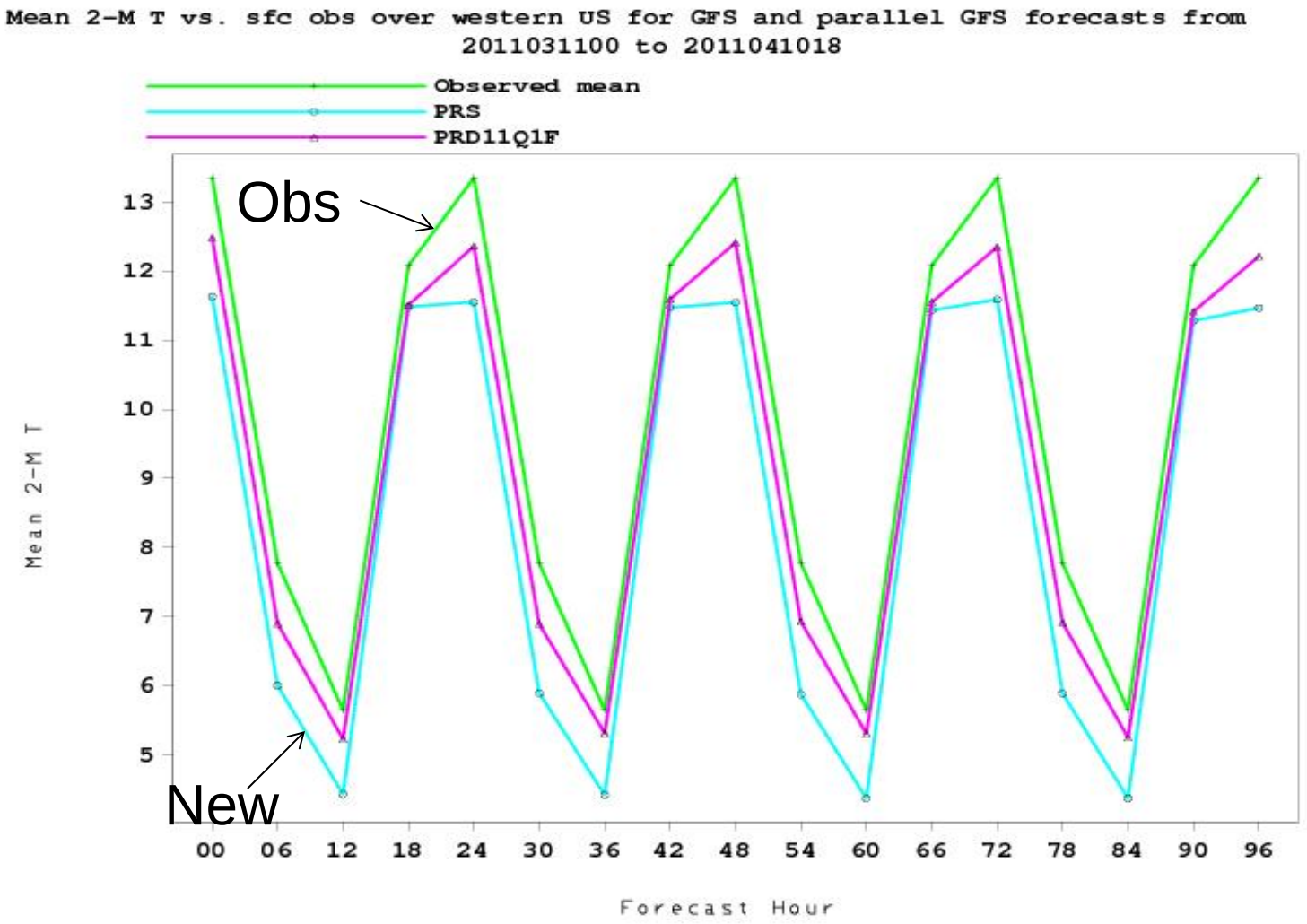


New

Time series over 100-120W, 50-60N



2m Ta over western U.S. for 1 month (11 Mar-10 Apr 2011)



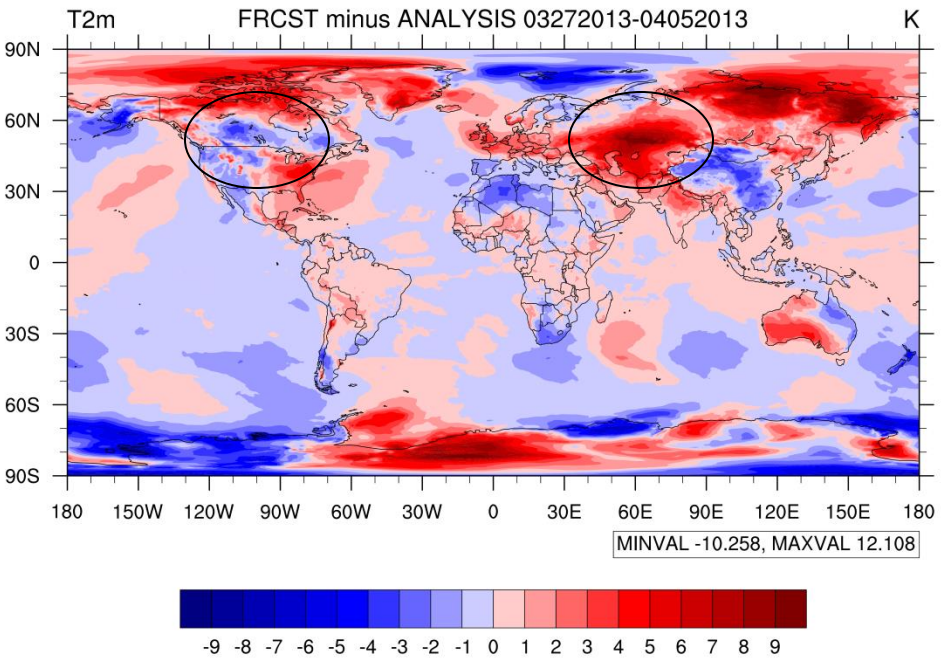
Better snowpack forecast does not necessarily lead to better prediction of 2-m air temperature

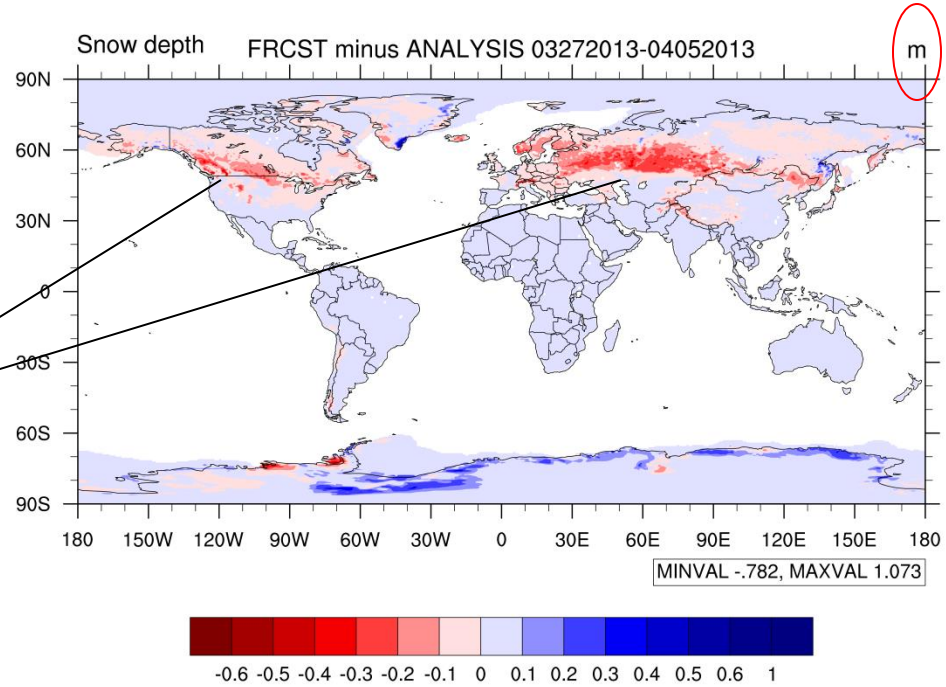
6-day GFS/Noah forecasting averaged for 10 days (3/27-4/5/2013) :

substantial early snow melt;
T_{2m} cold bias over NA but warm bias over Eurasia

Directly affect runoff

Geil et al. (2013)





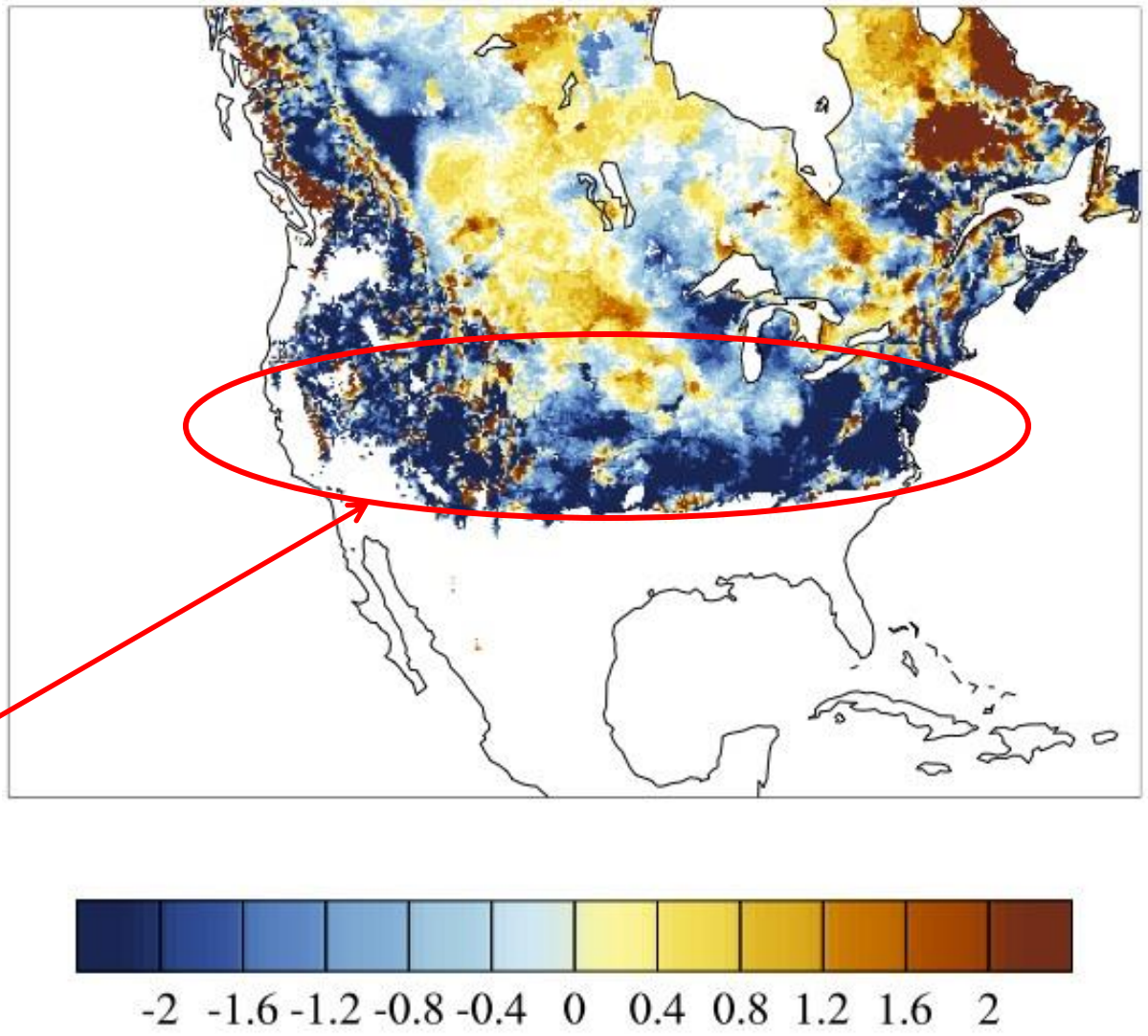
NCEP WRF-NMM SWE

SWE diff [mm] between 6-hr forecast and analysis in Feb 2010.

USAF snow depth product was assimilated

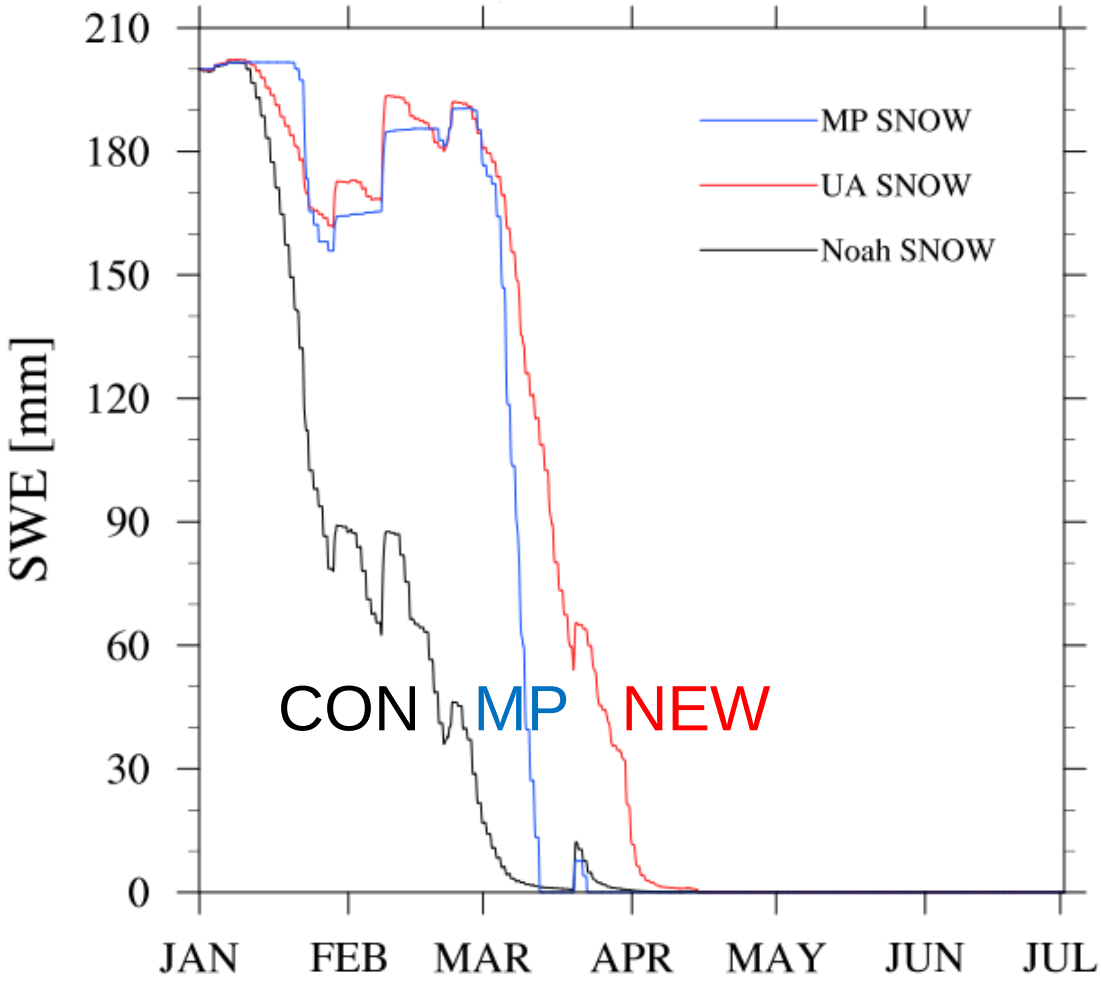
>2mm SWE are lost in 6 hours **on average**

consistent during all snow months



3. Impact of Noah improvements in WRF v3.4.1

Evergreen Needleleaf WRF Snow in an idealized 6-mon simulation



Our Noah improvements (UA) perform as well as the explicit canopy model (MP) at maintaining snowpack in spring.

Our improvements were released in WRF version 3.5 in Spring 2013

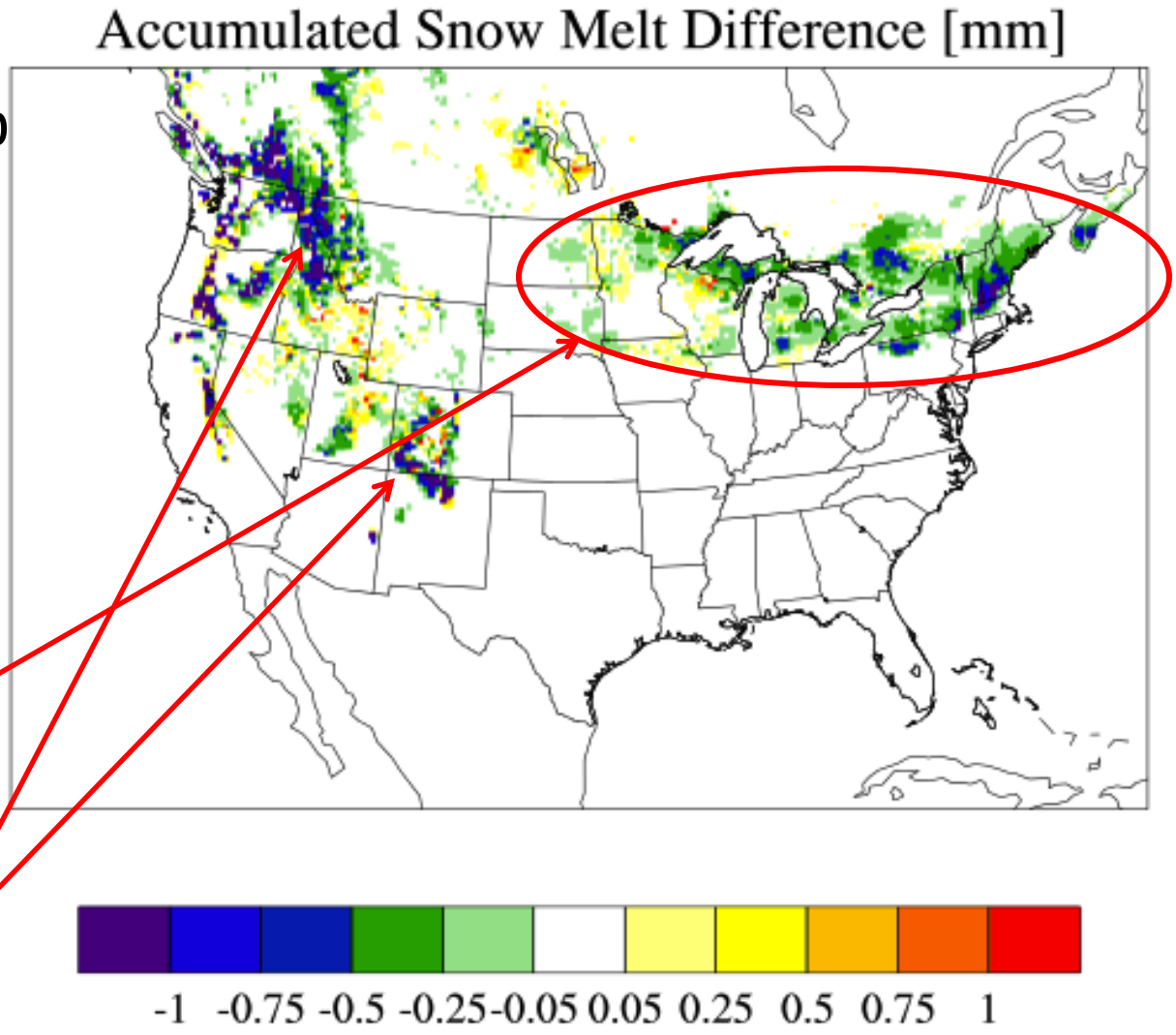
Barlage et al. (2012)

WRF/Noah_UA - WRF/Noah

36-hr forecast in Feb 2012, provided by DTC and based on the AFWA configuration testing domain

Noah modifications reduce snowmelt by about 1mm

Additional benefit against snow loss in mountains



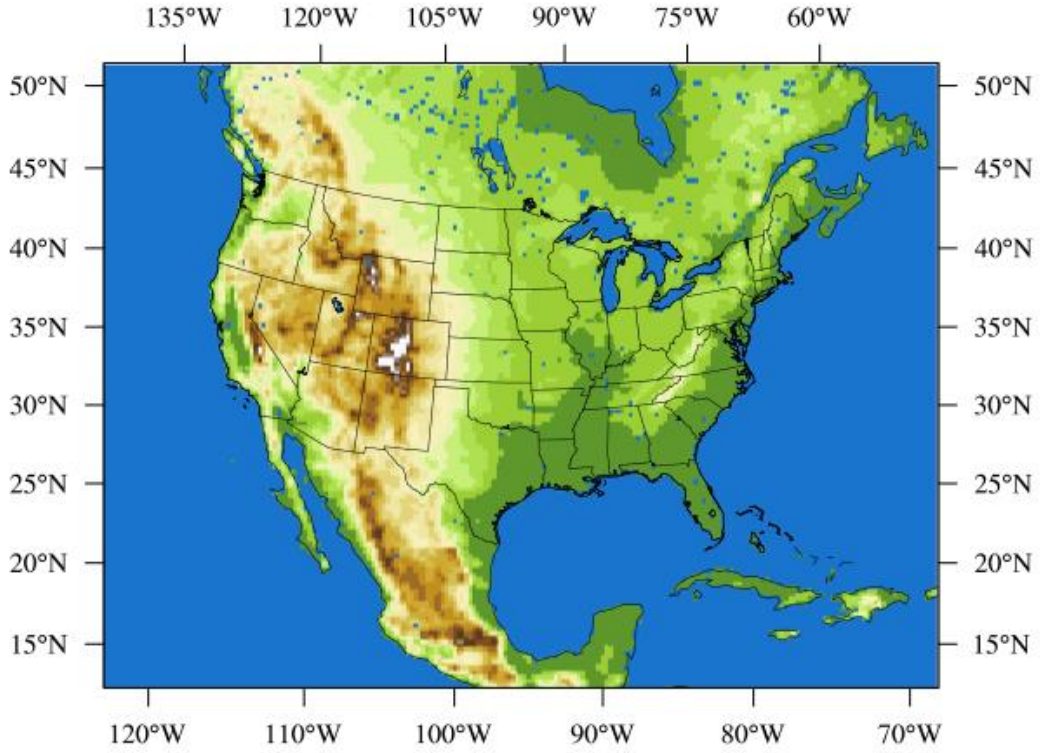
4. Noah vs. Noah-MP

Six-month 30km WRF simulations - 2010

Spin-up soil for one year using offline HRLDAS

IC/BC from NARR

Surface verification against ~2600 surface stations of T_{2m} and T_{d2m}



Barlage et al. (2013)

Noah vs. NoahMP

Model	Season	Output field	Day bias[ºC]	Day RMSE	Night bias[ºC]	Night RMSE
Noah	MAM	T_{2m}	-2.79	3.18	-1.95	2.17
Noah-MP	MAM	T_{2m}	**0.17**	**0.92**	**-0.01**	**0.77**
Noah	JJA	T_{2m}	**-0.04**	**0.75**	-1.04	1.37
Noah-MP	JJA	T_{2m}	1.09	1.53	**0.13**	**0.94**
Noah	MAM	Td_{2m}	-0.48	1.16	-1.29	1.64
Noah-MP	MAM	Td_{2m}	**0.19**	**1.04**	**0.48**	**1.01**
Noah	JJA	Td_{2m}	**-0.98**	**1.53**	-1.73	2.08
Noah-MP	JJA	Td_{2m}	-1.18	1.84	**-1.00**	**1.57**

Green: Noah-MP improves

Red: Noah-MP degrades: summer daytime

Underline: Better performance

Major R2O Achievements

3-yr project (6/2010 – 5/2013); budget: $340K

Improvements in Noah daytime Ts were implemented in GFS in May 2011

Noah snow improvements have been tested in GFS and are ready for implementation;

Noah snow improvements were released in WRF version 3.5 in April 2013

Noah-MP has become a land model option in WRF

Critical Issues

- Both CRTM development and GFS/Noah improvements are needed to accelerate satellite data use and forecasting improvement
- Noah improvements don’t necessarily improve atmospheric processes, because GFS had been tuned (for default Noah)
- We have to improve GFS and Noah together
- We have to improve GFS/Noah and CRTM together